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COMPETITIVE TRENDS OF ATLANTIC BLUEFIN TUNA FARMING AMONG MAJOR MEDITERRANEAN PRODUCERS, WITH SPECIAL EMPHASIS ON HUMAN CAPACITY BY POPULATION GROWTH

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Abstract

This study aims to investigate the economic dynamics among five major tuna producing countries in the Mediterranean: Malta, Spain, Türkiye, Croatia and Tunisia which provide significant amounts of tuna for the growing demand in the market network. Major drivers of the tuna farming were identified based on annual production yields provided by FAO statistics. The growth trends and economic development of the tuna production industries in the three key producers of tuna have been evaluated and superimposed with the increasing trends in population densities between 2006 and 2023. Tuna harvests from farms in Malta increased around 3-fold from 6,069 to 18,623.7 tons between in 2006-2023, while in Spain approximately 4-fold increase was noted in the last 18 years, from 2,572 to 10,652.8 tons. Among the five major producers in the Mediterranean, Türkiye increased its harvest by 9.4-fold between the same years, reaching 3,674 tons in 2023 from the relatively low level of 390 tons in 2006. Tunisian production increased by 3.2-fold from 450 to 1,439 tons between 2006-2023, whereas Croatian tuna farming declined by 0.49-fold from 6,700 to 3,242 tons over the past 18 years. In terms of economic gain, tuna producers of Malta achieved around 9% higher economic gain than Spain, and around 72, 83, and 94% higher economic efficiency than Croatia, Türkiye, and Tunisia, respectively. Considering the importance of skilled labor in production, the relationship between harvest volumes and population growth by country was examined through correlation. Strong correlation between production and population growth was observed in both Malta and Türkiye over the 18-year period (R=0.91, Malta; R=0.90, Turkey), whereas no such strong correlation was found in Spain (R=0.68), followed by Tunisia (R=0.49) and Croatia

(R=0.14) for the same years of investigation. The results of this study highlight the importance of manpower in the production and operational processes of the aquaculture industry, in addition to other factors. Furthermore, considering the need for more comprehensive studies on human capacity in aquaculture, findings of the present study shed light and encourage future research.

Keywords: Bluefin tuna, export, manpower, Mediterranean aquaculture, population growth

Introduction

For the global food security, marine cage aquaculture industry plays an important role with remarkable economic inputs for Mediterranean countries. While the economic dynamics of aquaculture depend on many factors, infrastructure, marketing networks, and human resources are important drivers for successful farm operations. Investments in infrastructure and human resources, in particular, may increase production efficiency over time, contributing significantly to business profits and economic growth (Hishamunda et al., 2009). Further, planning and management of production systems in aquaculture operations also depends on long lasting practices and are linked to skilled human resources and the availability of finance for beneficial outcomes (Verdegem et al., 2023). The shortage of manpower has been reported as one of the most significant challenges facing aquaculture producers (Engle et al., 2019; van Senten & Engle, 2017; van Senten et al., 2020a, b). Declines in trained human resources and manpower during the recent pandemic of Covid-19, for example, disrupted production processes, that in turn reduced yields and further result in food shortages. Lockdowns and border closures as measures for epidemic spreads, caused severe consequences for the supply chain of the food business (Maqbool et al., 2024). Dolgui et al. (2020) and Mahmood et al. (2022) underlined that the pandemic outbreak disrupted the global supply chain with goods shortages due to shipping delays, and increased transportation costs. Interruptions in logistics resulted in decline of manpower that further caused delays in good transportation, which broke the network of trade continuity and export distribution. Atlantic bluefin tuna (*Thunnus thynnus*), the most important tuna species in Mediterranean tuna farming industry, has a remarkable high value in the global fish trade market, making it a major contributor to Mediterranean Economy (Jelic Mrcelic et al., 2023). Therefore, any disruption in the production yields of tuna harvest, either due to manpower shortage, trade restrictions or price fluctuations may have severe impacts on economic indicators.

The present study aims to evaluate competitive economic trends of Mediterranean tuna aquaculture among the major producers of Malta, Spain and Türkiye, with a special reference to production quantity and economic value in the trade network with super-imposure of human population growth, a major driver to the availability of manpower. Through evaluation of several parameters, this study provides understanding of the vulnerability and resilience of the tuna cage farming industry under severe conditions during periods of crisis. The results of this study may help farm managers and policy makers to improve the strength of the supply chain resilience, contribute to future challenges and sustainability of tuna farming in the Mediterranean region.

Material and Method

Data collection and analyses

Production quantity for the Atlantic Bluefin tuna was back dated 16 years of market value and harvest yields from 2006 to 2023, and data collected using statistical query panels provided by

Food and Agricultural Organization. (2025a, b). Variables measured in the present study are provided as means ± SD. The growth trend of production yields over 16-years has been formulated following the equation provided earlier (Yigit & Kusku, 2022; Yigit et al., 2023);

$$HG = \frac{(FH - IH)}{IH}\ x\ 100$$

where,
HG: harvest growth of tuna in tons
FH: final year of tuna harvest in tons
IH: initial year of tuna harvest in tons

Sales price per unit for each export country has been calculated by dividing the production value by quantity following the equation of Yigit et al. (2023):

$$SPu = \frac{pv}{pq}$$

where,
SPu: unit sales price
pv: production value in $US
pq: production quantity in tons

Relative population growth was calculated using the following equation (Yigit et al., 2023):

$$RPG = \frac{(finP - iniP)}{iniP}\ x\ 100$$

where,
RPG: relative population growth
iniP: initial population
finP: final population

Statistical analyses
The correlation between the growth of population and increase of yields have been evaluated by using MacBook Pro, macOS Big Sur (11.7.3), running a Microsoft Excel program for Mac, based on the following formulae:

$$Correl\ (x, y) = \frac{\sum(x - \bar{x})(y - \bar{y})}{\sqrt{\sum(x - \bar{x})^2\ \sum\ (y - \bar{y})^2}}$$

where, $\bar{x}$ and $\bar{y}$ indicates the sample means for two different series, that was set as growth in tuna production in countries for Serie 1, and human population growth in countries for Serie 2.

Results and Discussion

Tuna farming constitutes an important fisheries industry in the Mediterranean and, with its continuous development and new investments, supports new employment opportunities (Miyake et al., 2003). With its high commercial interest, the Atlantic bluefin tuna (*Thunnus thynnus*) supports economic development of countries bordering the Mediterranean, via capture-based fattening aquaculture operations (Ottolenghi, 2008). The production of Atlantic Bluefin tuna in the Mediterranean has been steadily growing over the last decade and reached a peak level of 37,864.34 tons in 2023 (Food and Agricultural Organization, 2025c). While scientific research on tuna generally focuses on its biology and population dynamics, studies on the economic evaluation of tuna farming are quite limited (Bjørndal, 2023).

Five major producers of Atlantic bluefin tuna in the Mediterranean, identified by the annual production reports of FAO statistics (Food and Agricultural Organization, 2025a). Malta, Spain, Türkiye, Croatia and Tunisia, providing a significant amount of tuna for the growing demand in the market network, were evaluated in terms of their production performance and competitive economic trends. The present study investigates the growth and economic developments over the last 18 years because Malta, one of the largest tuna producers in the Mediterranean area, began tuna farming in 2006. Particular attention was paid to ensuring that data analysis was conducted over the same time-frame across all countries covered in the study. Therefore, the study focuses on growth and economic developments between 2006 and 2023.

Based on data evaluation in this study, Malta gave a first record of Atlantic bluefin tuna harvest with 6,069 tons in 2006 and reached 18,623.7 tons in 2023. Over the last 18 years, Malta provided a total harvest yield of 170,394.41 tons with around 3.07-fold growth from 2006 to 2023. Spanish production hit a peak of 13,145.3 tons in 2022, with a total production of 97,063.9 tons for the same time-span, that was around 4.14-fold increase from 2,572 to 10,652.8 tons in the last 18 years. Türkiye provided a total of 37,648 tons with around 9.42-fold growth from 390 tons to 3,674 tons between 2006-2023. Tunisia demonstrated a 3.2-fold production increase from 450 tons in 2006 to 1439 tons in 2023. Even though the total production yield (60,896.50 tons) of Croatian tuna farming over the past 18 years ranked third among the main producers, its production growth showed a 0.49-fold decline from 6700 tons in 2006 to 3242 tons in 2023. According to the latest statistical information (Food and Agricultural Organization, 2025a), Malta alone supplied nearly half (49.19%) of the total Mediterranean Atlantic bluefin tuna production, whereas Spain produced 28.13 %, Türkiye 9.7 %, Croatia 8.59%, and Tunisia 3.8% of the total production delivered to international markets from marine cage farming sites in the Mediterranean area (Figure 1).

In comparison of the economic gain among the main producers of the Mediterranean tuna farming industry, Malta demonstrated approximately 9%, 72%, 83%, and 94% greater economic income compared to Spain, Croatia, Türkiye, and Tunisia, respectively (Figure 2).

When evaluating the relationship through correlation between harvest volumes and population growth by country, in consideration of the importance of skilled human capacity in fish farms, a relatively strong correlation was assessed between production and population growth of both Malta (R=0.91) and Türkiye (R=0.90) over the past 18-years span, compared to Spain (R=0.68) and Tunisia (R=0.49), where no such strong correlation was found. The correlation between production and population growth for Croatia however was remarkably low (R=0.14), in comparison to the other main producers in the Mediterranean (Table 1).

Despite the fact that the highest production of Atlantic bluefin tuna was recorded in Malta (170,394.41 tons) between 2006-2023, the percent production increase was highest (842.05%) for the Turkish tuna production, followed by Spain (314.19%), Tunisia (219.78%), and Malta (206.87%). Percent production increase of Croatia, however declined by 51,46% over the past 18 years (Table 1).

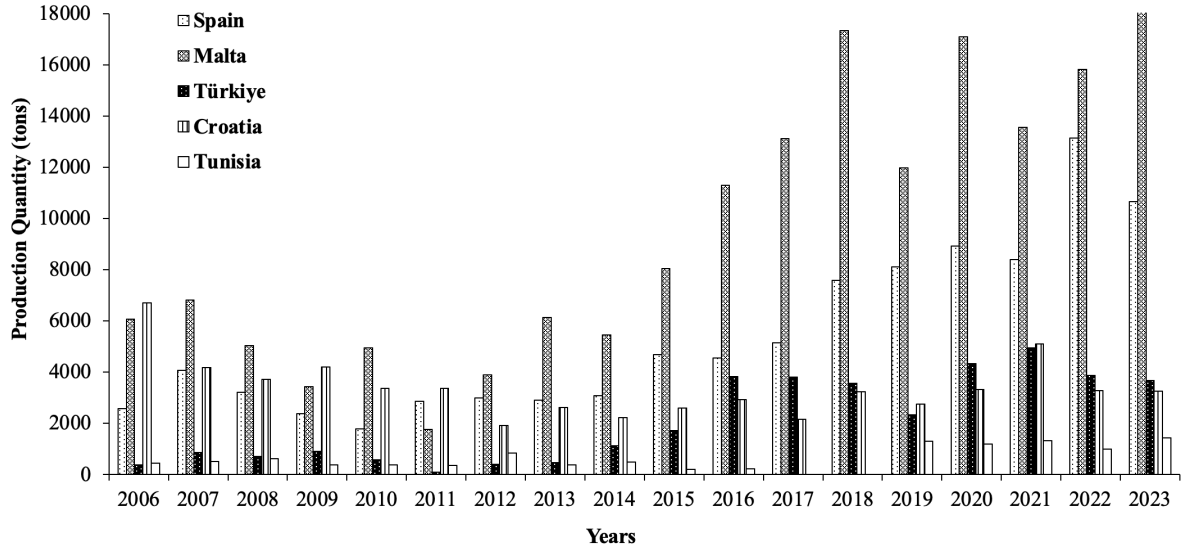

Figure 1. Production trend of Atlantic bluefin tuna in the Mediterranean (top five producers, 2006-2023) (produced based on data provided by the Food and Agricultural Organization, 2025a).

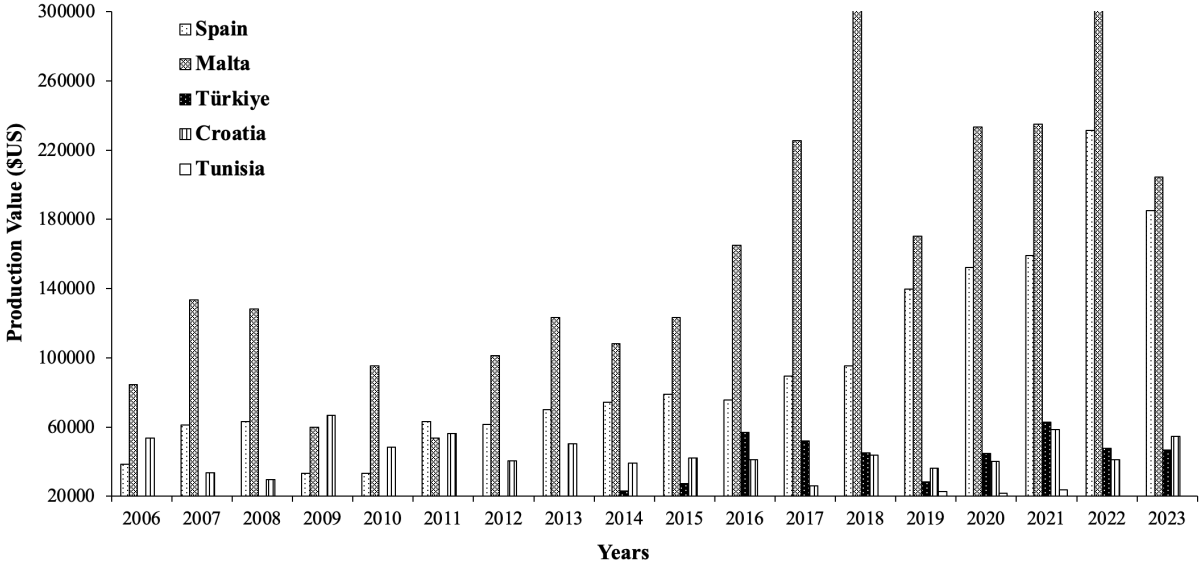

Figure 2. Production value of Atlantic bluefin tuna in the Mediterranean (top five producers, 2006-2023) (produced based on data provided by the Food and Agricultural Organization, 2025b).

Table 1. Total Atlantic bluefin tuna production, production growth in percent, and correlation between production growth (PG) and population increase (PI) in the top-five Mediterranean producers over the past 18 years from 2006 to 2023.

Country	**Malta**		**Spain**		**Croatia**		**Türkiye**		**Tunisia**	
Variables	**PG***	**PI****	**PG***	**PI****	**PG***	**PI****	**PG***	**PI****	**PG***	**PI****
Year										
2006	6069	415454	2572	44695448	6700	4315800	390	70045349	450	10346410
2007	6813	417197	4076	45516507	4180	4315954	870	70750586	511	10441702
2008	5039	418969	3216.7	46235054	3711	4314631	710	71562338	611	10542635
2009	3441	420795	2378.6	46635180	4200	4310530	910	72464848	380	10650681
2010	4955	422651	1793.4	46840471	3368	4301145	580	73346769	373	10765980
2011	1759	424628	2866	46998043	3368	4280824	100	74215203	350	10886035
2012	3904	426611	2987.7	47018323	1906.7	4259236	395	75197198	841	11009642
2013	6123	428452	2902.6	46860389	2616.3	4242398	470	76403031	380	11141361
2014	5451	434485	3088.4	46720188	2223.8	4219479	1136	78036154	479	11274288
2015	8051	444981	4690.7	46683686	2603.4	4183729	1710	80014226	199	11402264
2016	11292	455269	4562.3	46732771	2934.3	4136444	3834	81652088	218	11528674
2017	13120	467902	5136.1	46868596	2161.6	4079200	3802	83083662	0	11650498
2018	17326	484558	7574.6	47092821	3227.1	4024868	3571	84415969	0	11765514
2019	11970	504015	8107.8	47435119	2746.7	3986334	2327	85357672	1310	11875081
2020	17093	518207	8913.4	47679489	3323	3953958	4338	86091692	1194	11974057
2021	13548.8	524376	8399.5	47735664	5103.9	3924610	4952	86686253	1318	12048622
2022	15815.9	528192	13145.3	47828382	3270.7	3907027	3879	87058473	997	12119334
2023	18623.7	532956	10652.8	47911579	3252	3896023	3674	87270501	1439	12200431
∑-TP	170,394.41		97,063.90		60,896.50		37,648.00		11,050.00	
RGR	206.87		314.19		-51.46		842.05		219.78	
GFI	3.07		4.14		0.49		9.42		3.20	
Correlation	0.907959		0.681484		0.136632		0.897047		0.490741	

RGR: relative growth rate (percent production growth), 2006-2023
GFI: growth as fold-increase, 2006-2023
Correlation between production growth (PG) and population increase (PI), 2006-2023
∑-P: Total tuna production (2006-2023)
* PG: Food and Agricultural Organization (2025a)
** PI: Worldometer (2025a-e)

While many factors, such as infrastructure and marketing networks, play a role in the economic gains of aquaculture, human resources are particularly crucial for the success of production activities. Therefore, investments in human resources, as well as investments in infrastructure, may increase production efficiency and significantly contribute to the return on investment, thus driving the economic growth of the enterprise (Hishamunda et al., 2009). Despite the fact that long-term operational plans are necessary for successful business management in aquaculture facilities, qualified human resources, as well as the presence of financial resources, play an important role in achieving productive and efficient business goals (Verdegem et al., 2023). Earlier investigations highlight that one of the biggest problems in aquaculture enterprises is the shortage and continuity of manpower (Engle et al., 2019; van Senten & Engle, 2017; van Senten et al., 2020a, b). For instance, during the Covid-19 pandemic, one of the

largest epidemics Humanity has faced in recent times, countries restricted border crossings to prevent the spread of the epidemic, and even lockdowns resulted in a decrease of workforce, resulting in shortage of skilled human resources, that in turn affected the production process. Consequently, production efficiency decreased, leading to food shortages in many countries. Quarantines and border closures implemented as part of measures to combat the spread of the epidemic significantly affected the supply chain of food businesses (Maqbool et al., 2024), underlining the importance of human capacity and skilled manpower in food production, including aquaculture business. Further, delays in the transportation during the pandemic led to shortages in goods. The severe decline in manpower and human resources also affected the entire process, lead to increase production cost, transportation costs, that in turn created disruptions in the global supply chain (Dolgui et al., 2020; Mahmood et al., 2022). Obviously, earlier reports especially those evaluating the lockdown periods during pandemics, underlined the importance of human capacity in the entire food industry, including logistics, trade network linkage, export chain etc., that eventually highlights the close relation of manpower and the continuity of the food industry.

The aquaculture sector is crucial for meeting the food demand of the ever-growing world population, that is expected to reach around 9 billion in the next 20 years, and nearly 10 billion in year 2050, from its current 8.2 billion (Worldometer, 2025f). Aquaculture production worldwide reached 130.9 million tons, accounting for 51% of total aquatic production, that is expected to reach 205 million tons by 2032. The fisheries and aquaculture sector constitutes a significant source of income in the effort to meet the world's growing food demand. While the number of people employed in the fisheries and aquaculture industry, the primary sector of food production, was 62.8 million in 2020, this number decreased to approximately 61.8 million people in 2022 over the challenging times of pandemics. The proportional distribution of total employment in primary production was determined as 54% in fishing, 36% in aquaculture and 10% in other food sectors (Food and Agricultural Organization, 2024). As an outcome from these reports, it can be noted that the aquaculture industry will clearly have a greater responsibility in meeting the increasing food demand as the world's population grows, and issues such as employment and the availability of qualified personnel will become increasingly important. Therefore, while the growth of the aquaculture sector depends on many factors, such as finance, investment, technological advancements, it appears that the importance of the human factor will be increasingly discussed in the very near future.

Conclusion

Based on the correlation between tuna production growth with population increase on country basis, it can be predicted that a shortage of human capacity may constrain the sectoral development in countries with weak correlation of production growth versus population increase, such as the case in Spain (R= 0.68), Tunisia (R= 0.49), and Croatia (R= 0.14). In contrast however, population growth is compatible with production increase in Malta (R= 0.91) and Türkiye (R= 0.90), indicating that these two countries may have a wider availability of manpower with higher human capacity linkage to correlative population increase, with promising indication of the sustainable growth of farm activities and the future of the Mediterranean tuna aquaculture industry. The results in the present investigation highlight the importance of manpower in both production and operational processes of the food production activities such as the aquaculture industry, in addition to several other factors. Furthermore, considering the need for more comprehensive studies on human capacity in aquaculture, findings of the present study highlights and encourage future research.

Ethical approval
Not applicable as no humans or animals were involving in this study.

Informed consent
Not available as single author is present in this study.

Data availability statement
The author declares that data can be provided by corresponding author upon reasonable request.

Conflicts of interest
There is no conflict of interests for publishing this study.

Funding organizations
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Contribution of authors
Ümüt Yigit: Conceptualization, methodology, resources, data curation, analysis, writing original draft, finalizing paper.

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